

# EFFECTS OF GEOMETRY ON ELECTROMIGRATION LIFETIME OF CU INTERCONNECTS IN OXIDE DIELECTRICS

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The electromigration behavior of Cu interconnects has been a subject of significant technological and fundamental interest in recent years. Because of its high electrical conductivity and superior electromigration behavior, Cu has been chosen over Al-Cu as the preferred interconnect metallization for high performance devices (1). The processes used for the fabrication of Cu interconnects are significantly different from those used for Al-Cu. For example, instead of conventional RIE processing for line patterning in Al-Cu, dual Damascene in conjunction with CMP processes are used for Cu. The liner geometry along with liner materials and the processes of deposition are also markedly different between the two technologies. In addition to the basic material differences, namely a two phase alloyed conductor versus an essentially pure single component system, there have been many significant differences in other process variables to influence the electromigration behavior. For these reasons, a direct extrapolation of the electromigration behavior from Al-Cu to Cu is not valid. It has been shown in the literature that for Cu films deposited by the electroplating process, the grains are much larger than the sub-micron line width and surface transport is the dominant diffusion mechanism (2). The method of film deposition has been reported to have a strong effect on electromigration life (3). Cu films deposited by the electroplating process have superior electromigration life compared to the films deposited by physical vapor or CVD process. Literature shows (4) that line and via depletion are two primary modes of failure and the liner interface provides flux divergence and there exists a relatively weaker line length dependence.

Data will be presented to compare the lifetime differences between via depletion and line depletion failure modes. Typically, the median lifetime during the via depletion mode is several times longer compared to the lifetime for line depletion mode. The sigma of the distribution is observed to be relatively smaller for line depletion mode. The observed differences can be explained in terms of the via, the diffusion barrier (liner) geometry and the atom transport mechanism.

In order to project the reliability of the interconnect, it is important to understand the influence of the geometrical variables, namely the line width, the line overhang and the number of contacts. The width dependence of the electromigration lifetime will be presented for both line and via depletion mode of failure. It will be shown that the width dependence behavior differs markedly depending on the direction of electron flow and the electromigration lifetime is strongly influenced by the number of contacts.

In Al-Cu technology, the line overhang beyond the via landing has been reported to be a very important design feature influencing the reliability. In Al-Cu, it has been previously reported that the median lifetime increases linearly and the sigma of the distribution decreases with an increase of the degree of the line overhang and thus the current carrying capability of the lines can be significantly increased by incorporating the overhang feature in the design (5). Data will be presented to show that the overhang dependence of the electromigration lifetime in Cu interconnects is very different from the behavior reported for Al-Cu. A significant overhang dependence was observed for the via depletion mode of failure; however, such dependence was not observed for the line depletion. This difference in behavior between Al-Cu and the Cu technology will be explained in terms of the diffusion barrier (liner) characteristics in the interconnect.

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